RECEIVED
JAN 19
O. S. U.

I. C. 7192

November 1941

UNITED STATES
DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

BUREAU OF MINES
R. R. Sayers, Director

INFORMATION CIRCULAR

OCCURRENCES AND USES OF DOLOMITE IN THE UNITED STATES

BY

Shirley F. Colby

After this report has served your purpose and if you have no further need for it, please return it to the Bureau of Mines, using the official mailing label on the inside of the back cover.

I. C. 7192,
November 1941.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

OCCURRENCES AND USES OF DOLOMITE IN THE UNITED STATES[1]

By Shirley F. Colby[2]

CONTENTS

	Page
Introduction	1
Definition	1
Properties	2
Uses of dolomite and high-magnesian limestone	2
Uses for which chemical properties are important	3
Uses for which physical properties are important	11
Uses of limestone for which magnesium carbonate is usually objectionable	12
Dolomite as a source of magnesium	13
Occurrence	14
Occurrences and uses by States	14
Bibliography	19

INTRODUCTION

Much interest has been shown recently in the possible utilization of dolomite as a source of magnesium metal, a large production of which is deemed essential for national defense. As a result, many inquiries have been received by the Bureau of Mines as to sources of dolomite. This report has been prepared primarily to augment the Bureau's present published information on the occurrence of high-grade dolomite deposits in the United States. To supplement such data, the report also defines dolomite and related rocks and describes their properties and uses. The uses are covered in some detail in Information Circular 6524 entitled "Utilization of Dolomite and High-Magnesium Limestone," published in 1931 but now out of print. All essential data on uses contained in that report have been incorporated herein, and have been supplemented by data developed during subsequent years.

DEFINITION

Dolomite is a mineral composed of calcium and magnesium carbonates combined in equal molecular proportions, expressed by the formula $CaMg(CO_3)_2$. Dolomitic limestones contain considerable dolomite but also include either calcium carbonate or a physical mixture (not a chemical combination) of both calcium and magnesium carbonates. Ordinarily the term "limestone" means a rock containing less than 10 percent magnesium carbonate. Dolomitic limestones are classified as high-magnesian, containing 25 to 45 percent magnesium carbonate, and low-magnesian, containing 5 to 25 percent. Limestone with more than 95 percent calcium carbonate generally is referred to as high-calcium limestone. Inasmuch as magnesian limestones may be considered mechanical mixtures of the minerals calcite and dolomite, no sharp lines of demarcation have been established to designate the various gradations from high-calcium limestone to high-magnesian limestone to dolomite, which in its pure state is composed of 54.3 percent calcium carbonate ($CaCO_3$) and 45.7 percent magnesium carbonate ($MgCO_3$). Stated otherwise, pure dolomite contains 30.4 percent lime (CaO); 21.8 percent magnesia (MgO); and 47.8 percent carbon dioxide (CO_2). Mixtures of magnesite ($MgCO_3$) and calcite or magnesite and dolomite would contain higher percentages of magnesium carbonate than are present in high-magnesian limestone or dolomite, but aside from a few deposits of such composition in the far west such naturally-occurring mixtures are rare.

---

[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7192."

[2] Assistant economic analyst, Nonmetal Economics Division, Bureau of Mines.

PROPERTIES[3]

The hardness of dolomite is 3.5 to 4; specific gravity is 2.8 to 2.9, slightly more than that of calcite (specific gravity 2.72). Pure dolomite does not melt, but application of enough heat drives off carbon dioxide, leaving calcium and magnesium oxides. The temperature of this dissociation is about 850° C. or 1,562° F. Crystals of dolomite are pearly or vitreous. Granular dolomite, however, has a dull or earthy luster. Dolomite crystals are brittle and break with an uneven to conchoidal fracture. Fragments transmit light poorly or not at all. Certain physical properties such as porosity and crushing strength vary, depending on the source of the dolomite.

High calcium limestones effervesce freely in cold-dilute hydrochloric acid, but dolomite and high-magnesian limestones effervesce only if the acid is heated. If polished portions of magnesian limestone are etched by cold, weak acid and then examined under a microscope the true dolomite areas will be unaltered, but the calcium carbonate areas will show surface effects of solution.

USES OF DOLOMITE AND HIGH-MAGNESIAN LIMESTONE

More than three-fourths of the dolomite quarried in the United States is used as crushed stone for concrete aggregate, road metal, riprap and railroad ballast, and as a fertilizer and soil conditioner. The use of dolomite instead of crushed limestone or other crushed stone for these purposes depends on convenient location or favorable transportation facilities and is contingent mainly upon the physical properties of the stone.

---

[3] A considerable part of this section and the following section on uses has been taken from Bureau of Mines Inf. Circ. 6524, Utilization of Dolomite and High-Magnesium Limestone, by Paul Hatmaker, 1931.

Those uses that to a varying degree are dependent upon or affected by the magnesium content of dolomite include as refractories, as technical carbonate, in certain processes of paper manufacture, in some types of lime mortars, as blast-furnace flux, at glass works, in Vienna lime, as a source of carbon dioxide, in agriculture, in paints, calcimine, whitewash, and varnish, in ceramics, in the manufacture of rock wool and oxychloride cement, as a deacidifier of drinking water, in prepared whiting, in rubber preparations, at tanneries, in fungicides, and for such miscellaneous uses as in pig-iron casting, "pickling" iron and steel, wire drawing, and in the manufacture of strawboard.

A comparatively new use soon to be tried on a commercial scale is as a source of the metal magnesium.

Uses for Which Chemical Properties are Important

Refractories

Dolomite and high-magnesian limestone are used widely as substitutes for magnesite refractories in basic open-hearth steel furnaces and basic Bessemer converters; in lead-refining reverberatory furnaces, lead cupelling furnaces, and crucibles for lead blast furnaces; in copper converters and copper reverberatory furnaces; and in the form of crucibles for melting metals. Dead-burned material in various forms is commonly used, although raw dolomite may be employed for minor repair work.

Dead-burned dolomite is obtained by calcining dolomite or high-magnesian limestone to about 1,500° C. in either a blast furnace or a special kiln. At this temperature nearly all of the CO_2 is driven off, leaving CaO and MgO, which sinter to an extent depending on the amount of impurities present. The sintering action may be aided by the addition of such agents as iron oxide, alumina, and silica to the crushed dolomite before calcining. There is a general tendency to calcine refractories at higher temperatures, although this varies considerably, some being merely caustic calcined and others being burned at extreme temperatures.

Dead-burned dolomite is generally mixed with tar or a fluxing agent and either applied as a monolithic lining to the furnace bottom or formed into brick shapes, fired, and then laid in the same manner as other refractory brick.

In steel furnaces the sides and top are generally composed of silica brick. The bottom of the furnace is made up of a layer of insulating brick and on this 2 or 3 courses of high-heat-duty fireclay brick are laid. Then two or more courses of magnesite or chrome brick are added and stepped up at the sides. The monolithic hearth or basic bottom of dead-burned magnesite is spread directly on the chrome or magnesite brick. Refractory dolomite is used to repair the hearth and maintain its thickness. Where dead-burned dolomite is used as a substitute for magnesite in such basic furnace bottoms, the raw stone should contain less than 1 percent of silica, less than 1.5 percent of combined iron oxide and alumina, and at least 35 percent of magnesium carbonate, the rest being calcium carbonate. After each heat dolomite is spread uniformly over the surface to compensate for losses of the monolithic hearth surface. Large quantities of refractory dolomite are consumed in this manner. Crude dolomite is sometimes used on the banks and ends of the furnace. Ordinary dead-burned dolomite without additions of stabilizing materials is seldom used in the actual formation of a hearth.

The manufacture of dolomite brick that can successfully replace the more expensive magnesite brick has been accomplished only in the last 4 or 5 years. Dolomite brick are being used experimentally in open-hearth furnace bottoms and in arc furnaces, where, it is maintained, they have as long a life as magnesite brick and cost only two-thirds as much. Development of better spalling resistance is necessary, however, before they can be used in exposed positions in periodic furnaces where temperature changes are a factor.

The chief objection to dolomite refractories has been the high lime content, which, unless inhibited, may cause the dolomite to disintegrate either by hydration or dusting. Previously tar coatings were used to prevent hydration of dead-burned dolomite in storage, but when the material was exposed to high heat the protection afforded by the tar disappeared. Another process involves coating the grains with slag, which is effective as long as the glassy films do not crack. The most successful method is to convert the lime content into a nonslagging form such as the silicate. Stabilization of dolomite may generally be achieved by adding a siliceous material, such as magnesium silicate to retard hydration, and a stabilizer such as boric or chromic oxide to diminish dusting.

Commercial production of magnesitic-dolomite brick was begun in Canada in 1938, and since the outbreak of the war this industry has reached large proportions. Basic Refractories, Inc., in the United States, has also been manufacturing a basic refractory from dolomite; brucite and serpentine are added to increase the magnesia content, and the lime is converted to the orthosilicate, which is stabilized with chrome ore. The recent increased demand for steel and other metals has stimulated further research in methods of producing high-grade basic refractories from dolomite. Standard Lime & Stone Co. produces a refractory from the product resulting from leaching the slightly soluble calcium oxide from calcined dolomite with large quantities of water. Two other processes are now in the pilot-plant stage. One of them involves treatment of the calcined and slaked dolomite with hydrogen sulfide, and extraction of the calcium hydrosulfide with water. In the other method, the calcined dolomite is treated with sugar solution and the resulting calcium sucrate removed in solution. Another process under consideration involves manufacturing refractories from the high-magnesia sludge remaining after the lime content of calcined dolomite is utilized to recover ammonia in the ammonia-soda process for the production of sodium carbonate.

Technical Carbonate

Technical carbonate, often referred to as basic magnesium carbonate, block magnesia, or magnesia alba, is widely employed in the manufacture of pipe and boiler covering and for general insulation against heat. It is also used in certain pharmaceutical preparations, rubber manufacture, and as a constituent of certain paints, varnishes, glass, printing inks, tooth paste, cosmetics, table salt, and other commodities. It is usually manufactured from dolomite by the Pattinson process or a modification thereof. This process is described briefly as follows:

Dolomite is mixed with coke and calcined, thus driving off the carbon dioxide, which is recovered, purified, compressed, and cooled. The calcined stone, essentially a mixture of calcium and magnesium oxides, is slaked in water and then recarbonated with the recovered carbon dioxide. This results in the formation of an insoluble calcium carbonate and a soluble bicarbonate of magnesia ($Mg(HCO_3)_2 \cdot H_2O$). The calcium carbonate is filtered off, and the magnesium bicarbonate liquor is boiled, which drives off some of the carbon dioxide and precipitates a white, basic, hydrated magnesium carbonate somewhat variable in composition but considered as having the formula $4MgCO_3 \cdot Mg(OH)_2 \cdot 5H_2O$.

In manufacturing the so-called 85 percent-magnesia molded insulation, the technical carbonate is mixed with about 15 percent by weight of asbestos fiber and possibly other bonding agents, molded into the desired forms, dried for 5 or 6 days, and then cut to true dimensions with special machinery.

Paper Mills

One of the most important methods of making paper from wood is the sulfite process. This method, used principally with wood of confierous trees, involves digestion of the pulp in an acid liquor under high temperature and pressure until all constituents except cellulose are dissolved and removed. This acid liquor, a solution of magnesium and calcium bisulfites, together with more or less free sulfur dioxide is obtained by treating either milk of lime or wet limestone with sulfur dioxide, prepared by burning sulfur or iron pyrites in air.

Dolomitic or high-magnesian lime is preferred for preparing the acid liquor by the milk-of-lime process, because magnesium bisulfite is considered more stable, more soluble, milder, and more effective in its chemical action than calcium bisulfite, producing a softer and whiter pulp. The quicklime or hydrated lime employed in preparing this liquor should have not less than 94 percent of calcium and magnesium oxides combined, not more than 5 to 10 percent of carbon dioxide, and not more than 3 percent total iron oxide, alumina, silica, and other insoluble impurities.

Another method of obtaining the acid liquor is by the Jennsen tower system, whereby sulfur gases pass up through a tower packed with limestone.

A high-magnesian limestone is undesirable for this purpose, however, as it is said to break down and clog the tower, thereby hindering gas absorption.

The following table shows the production of dolomite for use as refractory stone, basic magnesium carbonate (technical carbonate), and in sulfite paper mills, and an estimate of total raw dolomitic stone quarried for these purposes, by years, for the period 1920-1940.

Lime Mortars and Plasters

High-magnesian limestones and dolomites are used extensively for making lime, the calcined product of limestone. Lime mortars are mixtures of hydrated lime, sand, and water to which portland cement may be added.

Either high-magnesian or high-calcium lime may be used for mortar; however, dolomitic lime makes a smaller yield because it slakes more slowly, thereby generating less heat and explanding less in volume. For this reason and also because the higher ultimate strength of dolomitic lime is a factor that seldom requires consideration in the selection of mortar, high-calcium lime is generally preferred for mortar. Magnesian lime, however, because of its greater plasticity, is popular for finishing-coat plaster. Extensive deposits of high-grade dolomite in northwestern Ohio produce a white, plastic hydrate, which has enjoyed nation-wide distribution.

Furnace Flux

A basic flux such as limestone is necessary to remove undesirable elements, particularly silica and alumina, from iron ore in the smelting process. In the production of pig iron, silica and alumina, which have a stronger affinity for lime and magnesia than for iron, form double silicates of lime and alumina or magnesia and alumina. These are fused into liquid slag, which floats on the molten iron. The slag also removes sulfur from the ore and sulfur and ash from the coke. About 900 pounds of flux are required for each ton of pig iron manufactured.

High-calcium limestone is generally used for blast-furnace flux, but high-magnesian limestone obtained from dolomite deposits that are exceptionally pure is used successfully at Bethlehem, Pa., and Birmingham, Ala. The use of pure or impure stone depends to a large extent on economic conditions. Silica and alumina in a fluxing stone do no real harm in a blast furnace, but they do make the fluxing stone less effective, increase consumption of slag and fuel, and retard production to a limited extent. If the price differential between an impure and chemically pure stone is enough to offset these disadvantages, an impure stone is preferred.

High-calcium limestone is required in the basic open-hearth process of making steel because the removal of phosphorous is an important function of the flux and calcium oxide has a greater affinity for phosphorous than magnesium oxide.

Sales of Dolomite and Dolomitic Lime for the Principal Uses, 1920-40

Year	Dolomite for -				Dolomitic lime for -				
	Basic magnesium carbonate		Dead-burned dolomite or refractory stone		Refractory (dead-burned) dolomite		To sulfite paper mills		Total calculated as raw stone.
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons
1920	57,300	$107,107	612,800	$742,020	316,293	$3,732,522	121,817	$1,347,321	1,546,000
1921	32,050	60,648	79,430	85,786	107,664	1,113,010	68,992	711,345	465,000
1922	53,170	79,313	146,640	172,251	348,838	2,813,946	70,000	650,000	1,037,000
1923	116,410	146,337	205,890	249,993	357,642	3,599,116	75,000	750,000	1,188,000
1924	98,160	129,390	309,010	287,137	328,659	3,209,257	70,000	625,000	1,204,000
1925	98,980	131,440	415,710	375,315	392,145	3,730,509	53,000	451,000	1,405,000
1926	72,850	110,560	511,300	458,802	386,715	3,593,731	52,600	482,000	1,463,000
1927	69,940	115,932	434,160	424,140	374,415	3,459,803	50,000	441,000	1,353,000
1928	94,200	122,260	522,850	509,502	488,761	4,283,036	46,000	359,000	1,687,000
1929	84,750	129,383	516,400	461,444	488,032	4,261,942	51,000	398,000	1,679,000
1930	111,740	189,219	453,350	356,025	351,740	3,045,082	38,400	295,000	1,345,000
1931	80,820	122,525	268,500	183,020	243,769	1,866,971	32,000	233,000	901,000
1932	62,930	82,822	72,240	45,186	135,733	1,055,339	24,000	148,000	455,000
1933	83,640	99,630	196,540	180,160	261,812	2,064,869	25,000	144,000	854,000
1934	83,970	101,677	300,180	287,030	324,868	2,698,414	30,000	196,000	1,094,000
1935	96,810	153,973	321,860	265,506	455,258	3,785,834	27,000	178,000	1,383,000
1936	126,260	211,958	401,320	391,561	596,751	4,887,243	40,000	266,000	1,801,000
1937	96,730	158,023	576,900	580,720	617,706	5,217,833	42,000	293,000	1,995,000
1938	62,540	99,684	263,930	274,624	366,626	3,095,355	42,000	288,000	1,144,000
1939	89,390	147,129	824,930	713,991	671,561	5,447,554	41,000	267,000	2,339,000
1940	80,210	105,028	857,950	632,582	867,909	6,925,328	59,000	390,000	2,792,000

Dolomite is preferred in the manufacture of ferrosilicon and ferromanganese because it fluxes off little of the silica or manganese.

The magnesia content of the slag may have an effect on its subsequent use. Many operators prefer 7 to 10 percent of magnesia in the slag when it is to be used for road building. If the slag is to be used for the manufacture of portland cement, however, the magnesia content should not exceed 3 percent.

Glass Manufacture

Limestone or dolomite may constitute from 20 to as much as 30 percent of some glass batches, serving as the alkaline-earth element in the batch. Limestone of uniform grade is essential because of the rigid control necessary in composition of the batch. Some purchase contracts stipulate that the lime content must not vary more than 2 percent. Because of its coloring effect, the iron content of the limestone should be low. Silica in moderate amounts is not detrimental, but the amount of sulfur and phosphorous present should be low. Either a high-magnesian or high-calcium lime may be used, depending upon the kind of glass to be produced and upon the method of production. High-magnesian lime is preferred in plants using automatic machinery. Magnesia has no effect on the color of the glass, it increases its stability and makes purification of the glass easier because it lowers the alkali content, minimizes danger of devitrification, and has a low coefficient of expansion, with the result that glass containing dolomite is more resistant to mechanical and thermal effects than is a lime glass.

A free-flowing, dead-burned, dolomitic lime with density and grain size approximately those of sand is being manufactured as a glass raw material. It eliminates losses resulting from air slaking and the hazard to workmen from the use of free lime.

Miscellaneous

Vienna lime. - Vienna lime is a high-magnesian lime analyzing around 55 percent calcium carbonate and 43 percent magnesium carbonate with traces of silica, iron, and alumina. Its principal use is for buffing numerous materials, such as nickel, brass, copper, pearl, celluloid, and other metal and manufactured articles, and for imparting an under surface blue to nickel after plating.

In the manufacture of Vienna lime, high-grade dolomite is carefully calcined by a special process, then cleaned, ground, packed in sealed containers, and sold to manufacturers of buffing compound. In selecting dolomite for this product, not only the chemical composition of the stone but also its texture, porosity, crystallinity, and even its fossil origin are significant.

Carbon dioxide. - The use of carbon dioxide has increased substantially in recent years because of its employment in solid form as a refrigerant. Although dolomite is used as a source of carbon dioxide, adequate supplies are also obtained from gas wells, coke processes, and as a byproduct of chemical and fermentation industries. The principal uses of this gas are in the manufacture of carbonated beverages, epsom salts, explosives, food preservatives, chemicals, and in fire extinguishers.

Agriculture. - Lime acts as a soil conditioner, correcting acidity and improving tilth. There has been some difference of opinion in the past as to the suitability of dolomitic limestones, but it is generally agreed that magnesium has value equal to calcium and that the agricultural value of the stone depends on the percentage of total carbonates present. In some regions a greater demand for dolomite has developed to feed "magnesium-starved" soils.

Experiments have revealed that the addition of pulverized dolomite to superphosphate fertilizers is advantageous. The addition of dolomite to complete fertilizers containing ammonium compounds prevents them from increasing soil acidity and also has the effect of preserving plant-food values that may be lost when high-calcium stone is used.

Limestone is being used increasingly as a filler in commercial fertilizers to add weight and reduce caking. It has the further advantage of possessing soil-correcting and fertilizing properties.

Paint, calcimine, whitewash, and varnish. - Finely-pulverized limestone is employed to a considerable extent as paint filler. Lime is used in the preparation of resins consumed in varnish manufacture, and hydrated lime is used for calcimines and whitewash. For most of these uses the relative quantities of calcium and magnesium carbonate in the raw stone is of little importance.

Ceramics. - Limestone is used to some extent in the manufacture of pottery and porcelain ware. It is used in the form of a carbonate as a levigated natural whiting, as a hydrate, or as an oxide. It aids in fluxing the various materials and in some instances a relatively high-magnesia content is preferable; whereas in others a high-calcium content is desired.

Rock wool. - Impure limestones or dolomites may be used for making rock wool, also known as mineral wool, names applied to fine, interlaced threads of calcium silicate used chiefly for insulation against heat and sound. The usual method of manufacture is to melt the rock in a cupola. The molten material issues from the furnace in a small stream and is atomized by a jet of steam into numerous fine, pliable, glassy, colorless fibers, which fall into a fluffy mass resembling sheep's wool.

Limestone or dolomite to be used for this purpose should contain between 20 and 30 percent carbon dioxide, equivalent to 45 to 65 percent of the combined carbonates of calcium and magnesium. The rest of the rock should be principally silica or silica and alumina. Magnesium carbonate and alumina are not necessary, although some manufacturers prefer them. Rock has been found that meets all of these specifications, but rock wool can also be made from limestone or dolomite mixed with shale, sandstone, or other siliceous or aluminous rocks, provided, of course, that the mixture meets the chemical and physical specifications enumerated above. Slag wool and glass wool are similar products.

Oxychloride cement. - Magnesia oxychloride cement, also known as "Sorel," is used for flooring, wallboard, and stucco. Although so far as is known no plastic magnesia adaptable to forming magnesium oxychloride cement is made from dolomite found in this country, promising research is being carried on. At present, magnesite and magnesitic dolomite are the common raw materials.

Deacidifier of drinking water. - Calcined dolomite has been used in Germany to deacidify drinking water. For this purpose dolomite is submitted to a controlled calcination, and a porous product consisting mainly of magnesium oxide and calcium carbonate is obtained. This product, used in filters, reacts with the free carbon dioxide in the water to form soluble bicarbonates, which increase the carbonate hardness of the water but render it noncorrosive. Water treated with this product not only loses its corrosive properties but also is capable of depositing a thin protective layer on iron pipes that already have begun to corrode. The rust absorbs free carbon dioxide, thus disturbing the balance between the carbon dioxide and calcium carbonate, causing some of the calcium carbonate to settle on the rust, which produces a protective coating on the pipe.

Prepared whiting. - Magnesian lime is employed in the preparation of a fine-grained pigment for coating paper. Inasmuch as a pure-white color is essential, the iron content must be low. This pigment is made by adding sodium carbonate to a suspension of freshly-slaked magnesian lime.

Rubber preparations. - Some manufacturers of soft-rubber goods employ dolomite or high-magnesian lime as hardening agents. High-calcium limes are used similarly in making hard-rubber products. Both kinds of lime may also be used to some extent as accelerators in the vulcanizing process and as bulking agents or fillers performing the same function as clay or diatomite.

Tanneries. - At the depilatory stage of leather processing lime is used extensively. High-calcium lime is generally used because it produces a softer leather, but magnesian lime is preferred in the manufacture of morocco leather.

Fungicides. - Either a magnesian or a calcium lime hydrate may be employed in the preparation of dry-mix-sulfur lime, which is used as a fungicide.

Minor Uses. - A limited amount of hydrated lime is utilized in casting pig iron, in "pickling" iron and steel, in wire-drawing, and in the manufacture of strawboard. Either magnesian or high-calcium lime may be used.

Uses for Which Physical Properties are Important

Building Stone

The quality of a building stone depends primarily upon its physical rather than chemical properties. These physical requirements include homogeneity of structure, high density, low porosity, and pleasing color, requisites not affected by the percentage of magnesium carbonate contained in the rock. Some authorities hold, however, that a true dolomite is to be preferred to a so-called magnesian limestone because of the slight difference in solubility between calcium and magnesium carbonates. Sulfurous gases in the atmosphere may cause the formation of crystals of calcium and magnesium sulfates, which are likely to grow and break the stone. Rocks consisting of alternate shallow layers of calcite and dolomite do not make satisfactory building materials. Many commercial marbles contain varying amounts of magnesium carbonate, and some are nearly pure dolomite.

Crushed Stone

The production of crushed stone has kept pace with the rapid growth of the use of concrete for highway construction and other building activity. The vast tonnage of concrete aggregate consumed consists mainly of limestone, although other kinds of crushed stone and also slag and gravel are used extensively. Crushed stone is also employed as road stone and railroad ballast. For all of these uses the physical properties of the stone are of paramount importance. Because of its relatively low price, such factors as availability and proximity to markets determine the choice between limestone and dolomite.

Although requirements of users vary, it may be said that in general aggregate should consist of clean, hard, strong, durable, uncoated fragments free from injurious amounts of soft, friable, thin, elongated, or laminated pieces. Alkalies, organic matter, soluble sulfides, and gypsum are regarded as undesirable. Road stone should resist abrasion and break into sharply-angular, chunky fragments.

Coal-Mine Dusting

If coal dust and fine incombustible dusts are combined in about equal quantities, dust explosions are prevented or their spread is retarded. Finely-ground limestone may be generously applied to the walls, floors, and roofs of the entries and rooms of coal mines as an aid in the prevention of coal-dust explosions. Either a magnesian or calcium limestone may be used, as the chemical content for this purpose is immaterial. The best dust is white, so that the proportion of inert material present is easily distinguishable, and low in silica, so as to avoid injury to the lungs of miners.

Asphalt Filler

Limestone or dolomite ground to such fineness that 80 percent will pass through a 200-mesh screen is used as filler in road asphalt-surface mixtures. Although the preparation of asphalt filler forms a considerable part of the business of some limestone-quarrying companies, it is generally regarded as a byproduct activity for the utilization of fine materials that otherwise might be wasted. Finely-ground limestone is also used as a filler in other products such as rubber, oilcloth, paint, and linoleum.

Miscellaneous Uses

Minor uses of limestone include its utilization for curbing, flagging, paving, rubble, riprap, roofing gravel, stucco, terrazzo, and artificial stone. Besides its use in construction, limestone is also used as a filter bed, in poultry grit, and for lithographic stone, a fine-grained magnesian limestone being used in Germany for lithographic purposes.

Uses of Limestone for Which Magnesium Carbonate is Usually Objectionable

For the purpose of clearly outlining the uses to which dolomite and magnesian limestones may be put, the following uses of high-calcium limestone for which high-magnesian limestones may not generally be substituted are mentioned.

Portland Cement and Natural Cement

Limestone is the major raw material of portland cement; about four parts of high-grade limestone are mixed with one part of clay or shale. The magnesium content of the limestone should be low enough so that the finished product contains less than 5 percent magnesia (MgO).

Water Purification

Lime is used to "soften" water by removing calcium or magnesium carbonate that has been dissolved and held in solution by carbon dioxide absorbed from the atmosphere. The lime combines chemically with the excess carbon dioxide to form calcium carbonate. This, together with the calcium carbonate previously held in solution as bicarbonate, is precipitated and removed by filtration or decantation. Because of the fact that magnesium carbonate is only slightly soluble in water, a high-calcium lime is preferred for this purpose.

Sand-Lime Brick

Sand-lime bricks are formed by mixing sand with a small proportion of hydrated lime (usually about 8 percent) and molding the resulting mixture in heavy presses. The bricks, which are then hardened under steam pressure, consist essentially of sand cemented together with calcium silicate. Lime used for this purpose must be very low in magnesium.

Silica Brick

Silica brick, used as a refractory in furnace linings, differs from sand-lime brick in that the bricks, after being molded, are carefully dried and then burned in a special type of kiln. Lime for this purpose should contain at least 92 percent available calcium oxide and not more than 3 percent available magnesium oxide.

Alkali Works

The manufacture of sodium carbonate has become an important chemical industry. In the manufacture of soda ash and caustic soda, limestone is employed extensively as a reagent. To prevent loss through the formation of insoluble residues, the magnesia and silica content of the limestone should be low.

Calcium-Carbide Works

To manufacture calcium carbide, limestone is fused in an electric furnace with carbon in the form of coke, charcoal, or coal. The magnesia content of the limestone should be less than 2 percent.

Sugar Refineries

Large quantities of limestone are used in the refining of beet sugar. The calcined lime for this purpose should contain at least 85 or 90 percent of sugar-soluble lime and not more than 3 percent of magnesium oxide.

Cyanide Process

The cyanide process for recovery of gold and silver involves the addition of quicklime or milk of lime to impart that is known as protective alkalinity. Experiments with dolomite disclose that it cannot be substituted satisfactorily for this purpose.

Basic Open-Hearth Steel Flux

Limestone flux is added primarily for the removal of phosphorous and sulfur. Inasmuch as magnesium is a poor remover of phosphorous, the permissible content of MgO is generally fixed at not more than 5 percent.

Dolomite as a Source of Magnesium

The National Defense program has stimulated production of magnesium metal, which is one-third lighter than aluminum and can be substituted for it in many products or combined with it to form strong, light alloys so important in the manufacture of airplanes and automobiles. At the present time an increasingly important use of magnesium is in pyrotechnics, especially in the form of incendiary bombs. Although dolomite is a potential source of magnesium, this metal in past years has been extracted from under-ground brines and sea water. Several new magnesium plants are now or soon will be under construction in the United States. One plant near Las Vegas, Nev., will produce magnesium from magnesia extracted from magnesite and brucite, and a plant at Permanente, Calif., which recently started operating one unit, utilizes magnesite as raw material. The Defense Plant Corporation has made arrangements for construction and operation of magnesium plants at Painesville, Ohio, Lake Charles, La., and Austin, Tex. The first two plants probably will use ground dolomite mixed with a waste by-product from the ammonia-soda-alkali process employed in nearby alkali works, while the third plant is expected to utilize byproduct magnesium chloride from the potash works at Carlsbad, N. Mex., and dolomite. The magnesium chloride will be electrolyzed to produce magnesium metal. The Painesville and Lake Charles plants will produce about 50 tons daily or 36,000,000 pounds a year, while the Austin plant will have a capacity for 24,000,000 pounds of metal annually.

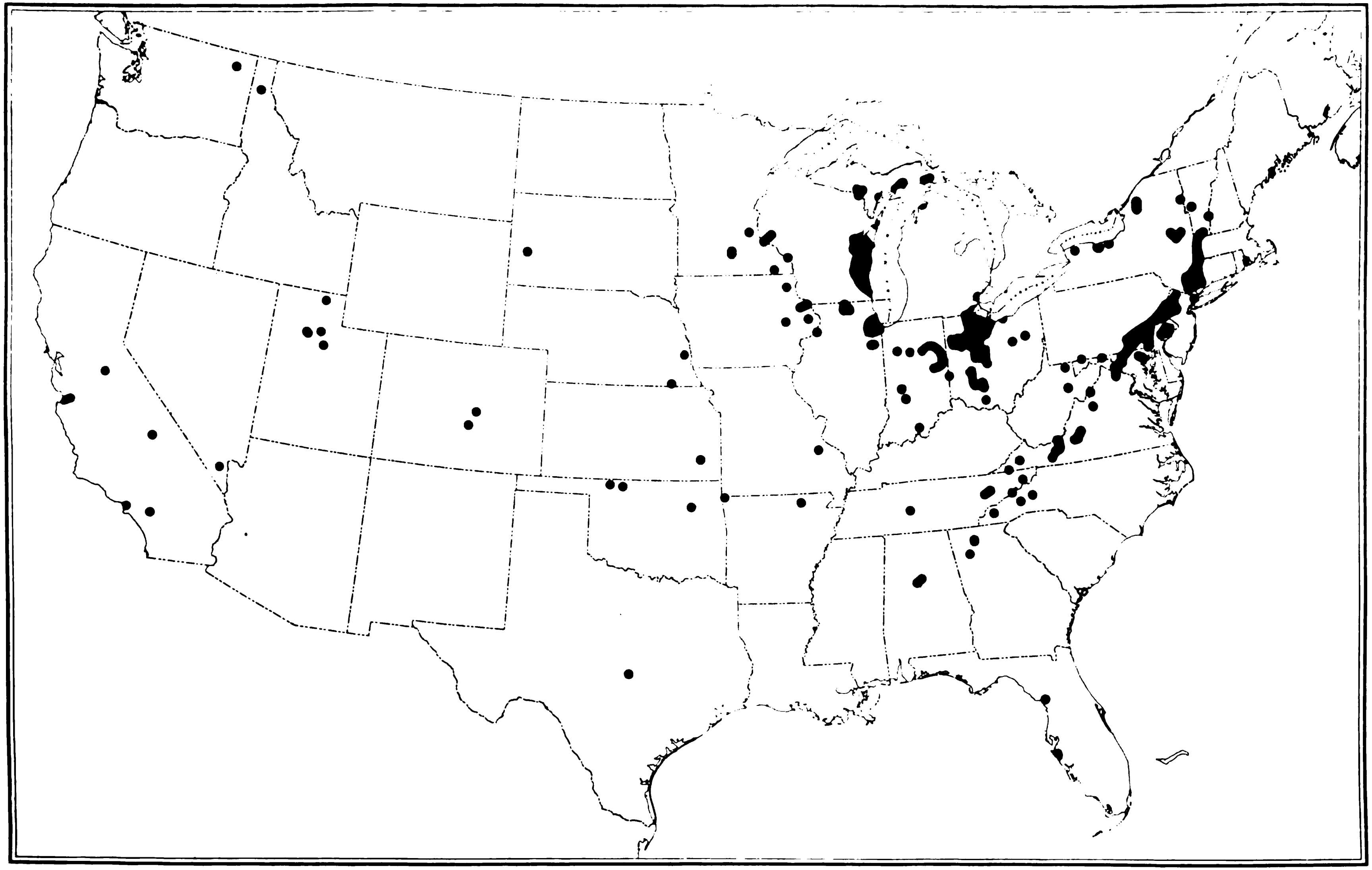
OCCURRENCE

Dolomite is found in many parts of the United States, particularly in the eastern half of the country, where most of the limestone occurs. The accompanying map (fig. 1) prepared by the Bureau of Mines shows locations where dolomite quarries are either in operation or have been worked in past years. This map is not intended to show all occurrences of dolomite in the United States. The areas shown are those only in which quarries of dolomite or high-magnesian limestone have been reported or called to the attention of this Bureau, and they are further restricted to deposits for which available analysis indicates a magnesium carbonate content of 25 percent or more for most of the deposit. Inasmuch as the most important uses of dolomite for which high-calcium limestone may not be substituted are in basic refractories and as a source of magnesia, dolomite deposits situated near industrial areas are quarried extensively. Dolomite deposits far from industrial centers have little commercial value as such, although they may be quarried and the rock used as crushed stone for road-building and in other types of construction activity and for agricultural purposes.

As shown on the accompanying map, the dolomite deposits exploited most extensively are in Ohio, Pennsylvania, and Wisconsin. Large quantities of dolomite and high-magnesian limestone are also quarried in Alabama, Michigan, New York, Massachusetts, Illinois, Indiana, and Virginia. The uses to which the stone is put differ somewhat in each locality.

OCCURRENCES AND USES BY STATES

Alabama. - The principal use of the high-magnesian limestone quarried around Birmingham is as flux in blast furnaces. Although opinions differ concerning the slagging effect of magnesia, dolomite has been used successfully in this region because the purest limestones are high-magnesian. Some of the stone quarried here is dead-burned for use as a refractory. Another important use is for dusting coal mines.



LOCATION OF HIGH-GRADE DOLOMITE QUARRIES IN THE UNITED STATES

The high-magnesian limestone quarried here is also utilized for agriculture, concrete, road metal, and as an asphalt filler.

Arkansas. - The dolomite quarried in Benton and Sharp Counties is used primarily for agriculture and construction. A small amount is used in glass manufacture.

California. - Dolomite quarries reported to the Bureau of Mines are located in Inyo, Los Angeles, Monterey, San Benito, and Tuolumne Counties. In Inyo County much of the dolomite is used as a refractory. In the other areas it is used largely as a flux, and in Tuolumne County it is also used as a source of magnesia, in glass factories, and for agriculture. Dolomite is used in the manufacture of CO_2 in Inyo, Monterey, and Tuolumne Counties.

Colorado. - Most of the dolomite quarried in Fremont County is employed as a refractory, although some is used as an aggregate in the manufacture of terrazzo. In El Paso County dolomite is dead-burned for refractory use.

Connecticut. - The dolomite in this State is used principally for agriculture, concrete aggregate, and road metal. Part of the Litchfield County high-magnesian limestone is used as a flux, and some is burned and used as mason's lime. Other uses of dolomite in this State are in glass factories and as a filler for rubber, asphalt, and paint.

Florida. - The high-magnesian limestone reported in Levy and Manatee Counties is used in agriculture and as concrete aggregate.

Georgia. - Dolomite quarries have been reported in Bartow, Gilmer, and Pickens Counties. The principal use of the stone is for agriculture and concrete aggregate. Other uses include flux, mason's lime, lime for use in prepared masonry mortar, asphalt filler, and terrazzo.

Idaho. - The high-magnesian limestone quarried in Kootenai County is used for furnace flux.

Illinois. - Dolomite quarried in the northern part of the State is employed in agriculture and as concrete aggregate and road metal. Near Thornton, Cook County, some of the dolomite is dead-burned for use as a refractory, whereas small quantities are employed as stone sand, asphalt filler, and filter beds.

Indiana. - Construction and agriculture absorb most of the dolomite produced in Indiana. In the eastern part of the State the principal uses are for glass manufacture, furnace flux, and the manufacture of mineral wool. In Cass County, dolomite is used for furnace flux and mineral-wool manufacture, and quarries in Owen and Putnam Counties in the west-central section find a demand for part of their stone as asphalt filler.

Iowa and Kansas. - Nearly all of the stone quarried in these States is used for construction and agriculture.

Maine. - The uses reported to this Bureau of the dolomite quarried in Knox County are in paper manufacture, agriculture, and construction.

Maryland. - A small part of the high-magnesian limestone quarried in Maryland is used as flux, but most of it is crushed and sold for concrete aggregate, road metal, railroad ballast, and agricultural purposes.

Massachusetts. - Although the general uses for agriculture and construction prevail, some dolomite is utilized as a refractory, in paper mills, and for manufacture of lime.

Michigan. - Dolomite quarries have been reported in the northwestern and southeastern corners of this State. In the southeastern fields, in Monroe and Wayne Counties, the product is used in paper mills and as furnace flux in addition to agriculture and construction. Mackinac County in the Upper Peninsula produces dolomite for refractories, and a large part of the high-magnesian limestone produced in Schoolcraft County is utilized as furnace flux. Dickinson County produces stone, which is used as a filler for paint and putty and for aggregate in terrazzo. As in nearly all States, however, the major fields of utilization are in construction and agriculture.

Minnesota. - Agriculture and the construction industries consume all of the dolomite quarried in Minnesota.

Missouri. - Dolomite is dead-burned for refractory purposes in St. Francois County, and in addition it is produced for furnace flux and agriculture.

Nebraska. - Two quarries in Nebraska reporting to this Bureau produce dolomitic limestone for concrete, road metal, and riprap.

Nevada. - A dolomite deposit in Clark County is quarried for use as a refractory and as flux in smelting ores.

New Jersey. - Agriculture and construction utilize all the dolomitic limestone produced in New Jersey.

New York. - The dolomite deposits in southeastern New York form a part of the outcrop belt flanking the eastern edge of the Appalachian Mountains from Vermont to Virginia. The principal use of this stone, aside from construction and agricultural purposes, is as asphalt filler. In Dutchess County small quantities are used in the manufacture of paper and in such products as paint, putty, soap filler, asbestos cement, and stucco. In Monroe and Niagara Counties several thousand tons a year is used as furnace flux. The dolomite quarried in other parts of the State is used for construction and agricultural purposes.

North Carolina. - Concrete and road metal and agriculture absorb all of North Carolina's product.

Ohio. - Ohio produces more dolomite than any other state in the country. In 1940 more than 800,000 tons was used as flux and more than 100,000 tons of raw stone was sold for refractory use. This does not include the much larger volume reported to this Bureau as dead-burned for refractory use. Sandusky and Seneca Counties produce more than half of the dead-burned dolomite consumed in this country. Northwestern Ohio is the most productive lime-producing area in the country, and most of the lime is high-magnesian. The lime in this region is particularly well adapted for use in finishing-coat plaster, which, because of its high plasticity, is widely used and distributed to all parts of the country. Mason's lime and prepared masonry mortar also are made here. Other large users of dolomite are nearby glass factories. Smaller quantities of the stone of this region are employed as rubber filler, dust for coal mines, asphalt filler, crushed stone for construction purposes, in the manufacture of paper, and in agriculture.

Another large dolomite-producing area runs from Clark to Adams Counties in southwestern Ohio. The Clark County product is used as a refractory, in paper manufacture, for the manufacture of Epsom salts, and for calcining into lime. In Clinton and Greene counties the stone is used both for furnace flux and as a refractory. The other Counties of this area and the other dolomite-producing regions of this State produce aggregate for concrete, railroad ballast, and agricultural limestone.

Oklahoma. - Quarries in Tulsa and Woods Counties produce dolomite, which is employed as an aggregate for concrete and for agricultural purposes.

Pennsylvania. - Montgomery County, situated in the midst of the extensive deposits in southeastern Pennsylvania, is an important source of dolomite used for making "85 percent-magnesia" pipe and boiler covering. This county also produces refractory stone and dead-burned dolomite, mason's lime and prepared masonry mortar, asphalt filler, and burned lime for use in tanneries. Magnesian lime is burned in Chester County for the manufacture of paper and mason's lime. Other counties in this region produce dolomite for furnace flux, refractories, magnesia, crushed-stone aggregate, and agricultural limestone.

South Dakota. - High-magnesian limestone in Pennington County is crushed for riprap, railroad ballast, road metal, and concrete aggregate.

Tennessee. - Agriculture and construction have consumed the major part of dolomite mined in this State. Part of the output of Knox County in the east-central area is employed as asphalt filler.

Utah. - Dolomite quarried for use as furnace flux has been reported from Salt Lake and Utah Counties. Tooele County produces dolomite that is dead-burned for use as a refractory and crushed for concrete aggregate.

Vermont. - The small quantity of high-magnesian limestone quarried in Vermont is used almost entirely for agricultural purposes.

Virginia. - Although dolomite quarries have been reported in a number of counties, Botetourt is the only one in which uses other than for construction and agriculture have been reported. These other uses are as furnace flux, asphalt filler, dust for coal mines, mason's lime, and prepared masonry mortar.

Washington. - Dolomite quarried in Stevens County is used by paper mills.

West Virginia. - Jefferson County, in the extreme eastern part of the State, produces substantial quantities of dolomite for use as flux and refractory in the Pittsburgh steel mills. The remainder of the output is utilized in construction and agriculture.

Wisconsin. - Although large quantities are used for ordinary crushed-stone purposes, a substantial tonnage produced in the extreme eastern part of the State is employed in the manufacture of technical carbonate and paper. Dolomite occurring in Dodge and Waukesha Counties is used for furnace flux and asphalt filler, and in Calumet, Dodge, Fond-du-Lac, Manitowoc, and Ozaukee Counties it is calcined into lime. An important dolomite product in Manitowoc County is Vienna lime, which is used as a polishing and buffing compound.

SELECTED BIBLIOGRAPHY

AMERICAN CERAMIC SOCIETY. Dolomite Earthenware. Jour., vol. 13, Nov. 1930. p. 952.

______. Preparation and Use of Dolomite Brick. Jour., vol. 13, June 1930, p. 437.

BEACH, J. O. and ENGLISH, S. G. Dolomite and Magnesium Limestone, Mineral Rept. No. 6, Oklahoma Geological Survey, April 1940, 17 pp.

BOLE, G. A. The Utilization of Dolomite for Refractories. Bureau of Mines Rept. of Investigations 2627, 1925, 11 pp.

BOLE, G. A., and SHAW, J. B. The Cuastic Calcination of Dolomite and Its Use in Sorel Cements. Jour. Am. Ceramic Soc., vol. 5, 1922, pp. 817-822.

BOWLES, OLIVER. The Stone Industries. McGraw-Hill Book Co., New York, 2d ed., 1939, 519 pp.

______. Metallurgical Limestone, Problems in Production and Utilization. Bureau of Mines Bull. 299, 1929, 40 pp.

______. Utilization Problems of Metallurgical Limestone and Dolomite. Am. Inst. Min. and Met. Eng. Tech. Pub. 62, 1928, pp. 1-14; also Iron and Steel Technology in 1928. Am. Inst. Min. and Met. Eng., pp. 87-102.

BOWLES, OLIVER, and BANKS, D. M. Limestone, Pt. I-General Information. Bureau of Mines Inf. Circ. 6723, June 1933, 21 pp.

BOWLES, OLIVER, and JENSEN, MABEL S. Limestone and Dolomite in the Chemical and Processing Industries. Bureau of Mines Inf. Circ. 7169, May 1941, 15 pp.

BRICK AND CLAY RECORD. Steel Industry Favors Dolomite and Chromite Refractories Over Magnesite. Vol. 79, July 28, 1931, pp. 80-82.

CANADIAN MINING AND METALLURGICAL BULLETIN. Dolomite. Vol. 217, May 1930, p. 543.

CEMENT, MILL AND QUARRY. Making Caustic, Dead-Burned Magnesia and Dolomite. Vol. 26, May 20, 1925, p. 21.

CHARRIN, F. Dolomite. Argile, No. 175, 1937, pp. 1-3. Ceram. Abs., vol. 17, no. 3, March 1938, p. 122.

CHEMICAL ABSTRACTS. Magnesia, etc., from Dolomite. Vol. 24, May 20, 1930, p. 2555.

CHEMICAL AND METALLURGICAL ENGINEERING. Dolomite in Fertilizers. Vol. 40, No. 4, April 1933, p. 188.

CHESTERS, J. H. Recent Developments in Basic Refractories Increase Furnace Applications. Brick and Clay Record, vol. 95, No. 5, Nov. 1939, pp. 57-58.

COPPS, EDWARD, JR. Pure-white Pigments and Aggregates are Made from Dolomite. Pit and Quarry, vol. 20, Sept. 24, 1930, pp. 22-26.

DOW, H. H., AND BARSTOW, E. O. Utilization of Dolomite or Magnesian Limestone for Production of Magnesium, etc. U.S. Pat. 1,749,210-1,4.3.30. Appl. (A) 30.10.26, (B) 8.11.26.

DOW, L. M. Crushed Stone Sand. Rock Products, vol. 35, No. 2, Jan. 30, 1932, pp. 63-64.

EYANY, DJEVAD. Magnesite from Dolomite. Rock Products, vol. 24, Nov. 19, 1921, p. 25.

FRANKE, HERBERT A. Out Magnesium Resources. Mining Cong. Jour., vol. 27, No. 8, August 1941, pp. 16-22.

GLASS INDUSTRY. A New Lime Glass. Vol. 17, No. 8, Aug. 1936, p. 279.

GOUDGE, M. F. Rock Wool. Jour. Canadian Ceramic Soc., vol. 4, 1935, pp. 10-16.

_____. Limestone and Lime - Their Industrial Uses. Min. and Met., vol. 18, No. 368, Aug. 1937, pp. 371-374.

HATMAKER, PAUL. Utilization of Dolomite and High-Magnesium Limestone. Bureau of Mines Inf. Circ. 6524, Sept. 1931, 18 pp.

_____. Lime. Chap. XXII, Industrial Minerals and Rocks, A.I.M.E., New York, 1937, pp. 413-422.

HENTON, HUGH M. The Pyro- and Hydro-treatment of Magnesite and Dolomite. Min. and Met., vol. 7, No. 1573-E, April 1926, 34 pp.

HOLMES, M. E., McCAUGHEY, W. J., AND BOLE, G. A. Dolomitic Clinker as a Stable Basic Refractory. Rock Products, vol. 32, July 20, 1929, pp. 59-67.

IMPERIAL INSTITUTE. The Use of Calcined Dolomite in the Treatment of Water. Bull., vol. 45, No. 1, Jan.-Mar. 1937, p. 89.

JONES, J. Dolomite and Its Uses in Glass Making. Glass, vol. 14, 1937, pp. 184-185.

KALLAUNER, O. Dolomite Bonding Materials. Jour. Am. Ceram. Soc., vol. 12, Sept. 1929, p. 662.

KEENAN, F. G., AND MORGAN, W. A. Rate of Dolomite Reactions in Mixed Fertilizers. Ind. and Eng. Chem., vol. 29, No. 2, Feb. 1937, pp. 197-201.

KNIBBS, N. V. S. Lime and Magnesia. D. Van Nostrand Co., New York, 1924.

KRIEGER, A. Dolomite Occurs in Two Natural Forms with Unlike Characteristics. Pit and Quarry, vol. 18, June 19, 1929, p. 51.

LAMAR, J. E., AND WILLMAN, H. B. A Summary of the Uses of Limestone and Dolomite. Illinois State Geological Survey Rept. of Investigations, No. 49, 1938, 50 pp.

LEAVER, E. S., DAVIS, C. W. AND WOOLF, J. A. Calcined Dolomite as a Substitute for Lime in the Recovery of Gold and Silver by the Cyanide Process. Bureau of Mines Rept. of Investigations 2648, 1924, 7 pp.

MACINTYRE, W. H., AND SHAW, W. M. Reactivity Between Dolomite and Superphosphate Components. Ind. Eng. Chem., vol. 24, 1932, pp. 1401-1409.

MILLER, BENJAMIN L. Limestones of Pennsylvania. Pennsylvania Geol. Surv. Bull. M 7, 1925, 368 pp.

NATIONAL LIME ASSOCIATION. Lime, Its Use and Value in the Industrial and Chemical Processes. Bull. 210, 1930, 88 pp.

PARSONS, L. M. Dolomite. Quarry and Surveyors and Contracters Jour., vol. 28, July 1923, London, pp. 196-200.

PATTERSON, SEELY B. Crushed and Broken Stone. Chap. XLIII, Industrial Minerals and Rocks, A.I.M.E., New York, 1937, pp. 801-809.

PLATZMANN, C. R. Production of Magnesia from Dolomite. Rock Products, vol. 32, Oct. 12, 1929, pp. 75-77.

RALSTON, O. C., PIKE, R. D., AND DUSCHAK, L. H. Plastic Magnesia. Bureau of Mines Bull. 236, 1925, 111 pp.

ROBSON, JAMES T., AND WITHROW, JAMES R. Dead-burning of Dolomite. Jour. Am. Ceram. Soc. vol. 7, Jan. 1924, p. 61; Feb. 1924, p. 141, Mar. 1924, p. 207; April 1924, p. 300; May 1924, p. 397.

ROCK PRODUCTS. Magnesia from Dolomite. Vol. 32, Oct. 26, 1929, p. 98.

ROCK PRODUCTS. Ground Dolomite for Fertilizer Filler. Vol. 35, No. 25, Dec. 31, 1932, p. 53.

SCHALLIS, ALVIN H. Dolomite Refractories. Bureau of Mines Mineral Trade Notes, vol. 12, No. 5, May 20, 1941, pp. 24-25.

SEARLE, ALFRED B. Magnesian Limestone and Some of Its Problems. Cement, Lime and Gravel, vol. 4, Aug. 1930, pp. 323-327.

_____. Limestone and Its Products. Ernest Benn, Ltd., London, 1935, 709 pp.

SHAW, J. B., AND BOLE, G. A. Big Possibilities for the Use of Dolomitic Limestone. Rock Products, vol. 25, Dec. 16, 1922, p. 15.

_____. New Developments in Oxychloride Stucco and Flooring. Jour. Am. Ceram. Soc., vol. 5, June 1922, p. 311.

SHEAD, A. C., AND HEINRICH, B. J. Determination of Calcium and Magnesium in Dolomitic Limestones by Means of Saccharate Solutions. Ind. and Eng. Chem., vol. 2, Oct. 15, 1930, p. 388-389.

STEWART, D. W. Developments in the Preparation of Calcium-Magnesium Bisulphite Liquors. Canadian Chem. and Met., vol. 12, Aug. 1928, p. 227.

TYLER, PAUL M. Magnesium Compounds (Other Than Magnesite.) Bureau of Mines Inf. Circ. 6406, Feb. 1931, 19 pp.

WHITLATCH, GEORGE I., Limestone and Lime. Tennessee Dept. of Conservation, Markets Circular No. 10, April 1941, 38 pp.

ZSCHACKE, ___. Magnesia as a Raw Material for Glass. Glashütte, vol. 67, No. 42, 1937, pp. 643-645; Ceram. Abs., vol. 17, No. 5, May 1938, p. 179.